While the term "biology" encompasses all living things, the "Biology" section of the GSL plan focuses on the wildlife species for which DWR is responsible, and on the physical and biological habitats which support those resources. The volume of biological information the planning team identified in its resource inventory is enormous. The team has endeavored to identify and synthesize that information which is relevant to the management responsibilities of DNR. While a great deal is known about many of the species present in the GSL ecosystem, information about many species is not well known, and biological interrelationships and the effects of environmental stressors are not understood in many instances. The lack of information on natural systems was a primary reason for DWR forming the Great Salt Lake Ecosystem Project (GSLEP).

Based on the information received during internal and external scoping, the planning team identified four major areas of management interest and concern:

- **Existing DWR management programs need to be considered.**
- **Changes in lake brine salinities, with corresponding impacts to aquatic and avian populations and ecological interactions on GSL are significant concerns.**
- **Potential for changes in lake water quality and impacts to aquatic and avian wildlife are concerns.**
- **WMAs within the 39 townships identified by the Utah Code for that purpose have indefinite boundaries.**
- **The planning team has identified Ramsar designation as a resource concern in this planning process.**

## Introduction

GSL and its environs support a number of diverse plant and animal species in a unique mosaic of upland, wetland, mudflat, river delta, brackish and freshwater marshes, ephemeral ponds and other habitat types. There are 250 species of birds which occur within the GSL ecosystem, of which 83 species are waterbirds that include 23 regularly occurring shorebirds and 11 that are seen occasionally. (Utah Ornithological Society, Bird Records Committee, 1998) GSL environs host 23 species or subspecies of fish which are found in impounded freshwater inflow areas, eight species of amphibians and 64 species or subspecies of mammals. From the federal listing, one threatened species (Bald eagle) and 15 sensitive species (which includes the American pelican and the Long-billed curlew) occur on and around GSL.

At least six uniquely productive wetland and water environments exist in the GSL ecosystems. These systems provide abundant and diverse habitat for the numerous wildlife species that use the lake system. These are:

Open-water environments of varying salinities
Island and upland habitats associated with the saline system
Freshwater lacustrine wetlands associated with river and stream deltas
Brackish-water areas of fresh and saline water interface
Spring-fed isolated wetlands
Mudflat/playa shoreline associated environments

While habitat attention generally focuses on the GSL's wetlands, adjacent upland areas are heavily used by wildlife and provide linking habitat types which create the highly productive marsh ecosystems. Upland areas provide an extraordinary amount of food, opportunities for cover, and buffer wetlands from expanding urban and industrial developments around the south and east sides of the lake. In addition, the lake is tied to the Wasatch Mountains by ribbons of riparian habitat which, in the desert west, are critical migratory and breeding habitats for a wide variety of wildlife, especially neotropical migrant songbirds, raptors and riverine mammals. The latitude of the lake makes it a significant wintering area for a number of species.

## International, Hemispheric and National Significance of Great Salt Lake

The GSL wetland ecosystems have been recognized nationally, hemispherically and globally for their importance as a vital link in a migrational corridor for water birds which extends from South America to the Arctic. It has also been designated as a Hemispheric Reserve of the Western Hemispheric Shorebird Reserve Network (WHSRN), and is being considered for nomination by the Ramsar Convention on Wetlands of International Significance for listing.

## Ramsar

An international convention was held in Ramsar, Iran, in 1971, to discuss the importance of wetland conservation worldwide. The name Ramsar was derived from the host city. The organizations that formed and support the Ramsar process are: the Asian Wetland Bureau, the International Waterfowl and Wetlands Research Bureau and Wetlands for Americas. The Ramsar Convention provides the framework for international cooperation for the conservation and wise use of wetlands (Ramsar, 1999a).

One outcome of the meeting was a process to offer special recognition to wetlands of international importance that met established criteria. A nomination process was put in place and recognition given to wetlands that qualified. Worldwide there are 113 Contracting Parties that have designated 957 sites for the Ramsar List, covering over 70.4 million hectares of wetlands (Ramsar, 1999c). There are 15 sites in the U.S. that recognize 1,163,690 hectares. Canada has 33 sites with 13,030,568 hectares.

Wetlands are selected on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology (USFWS, 1999a). Ramsar sites meet at least one of the following criteria:

Exemplify a specific wetland type characteristic of its region

> Have special value as habitat for rare, vulnerable, endangered or endemic species or because of the quality and peculiarities of its flora and fauna Support 20,000 waterfowl or substantial numbers from particular groups of waterfowl, shorebirds or waders indicative of wetland values, productivity or diversity. (Ramsar, 1999b)

The Ramsar Convention contracting parties are encouraged to develop national wetland policies and legislation to protect wetlands in their territory. Four main commitments for contracting parties include:

1. Listed sites. Wetlands are selected based on significancy in terms of ecology, botany, zoology, limnology or hydrology. Contracting parties develop specific criteria and guidelines for identifying sites that qualify for inclusion in the list of Wetlands of International Importance.

2. Wise use. General obligation to include wetland conservation considerations in land-use planning. Steps are taken to implement national planning that promotes the wise use or managing sustainable wetlands.

3. Reserves and training. Contracting parties establish reserves in wetlands whether or not they are on the Ramsar List and they are expected to promote wetland training.

4. International cooperation. Contracting parties consult with each other about implementation in regard to shared water systems, species and wetland linkages. (Ramsar, 1999b)

At least one site is designated for inclusion in the List of Wetlands of International Importance (Ramsar List). Ramsar List acceptance acknowledges the international importance and obliges the contracting party to take all steps necessary to ensure maintenance of the special ecological characteristics of the site, however management remains the responsibility of the contracting party. (Ramsar, 1999c)

According to the Ramsar website, this designation has played an important role in helping to prevent detrimental changes to wetland sites from:

> dredging for a marina development in Canada.
> mining in South Africa
> agricultural development in Hungary
> (Ramsar, 1998)

Several years ago a nomination process was initiated to designate the lake as a Ramsar site. This was taken before RDCC and the process was tabled. The nomination was made by the National Audubon Society and perhaps others. GSL qualifies for this designation. However the convention also places general obligations on contracting parties relating to the conservation of wetlands and special obligations pertaining to those wetlands which are designated as Ramsar sites (Ramsar, 1999a). The planning team is concerned that this designation may not be compatible with the multiple-use management framework to the extent it can be implemented consistent with the Public Trust Doctrine.. The consequences of this designation and associated obligations could limit the states ability to respond to changing demand for public trust resources. Other Ramsar sites in the U.S. have a clear wildlife and habitat

protection management focus. The state has broader management responsibilities, direction and objectives for the lake as a public trust resource.

A similar designation has been given to the lake recognizing its value to shorebirds. The WHSRN recognition carries no regulations or stipulations, simply a special recognition of the significant values.

The WHSRN was formed in 1985 to address serious concerns for shorebird population decline throughout North and South America. This group of government and private agencies is committed to shorebird conservation. The minimum criterion for designation is that the area must support more than 20,000 shorebirds or five percent of a flyway population. This international cooperative program is helping to protect key shorebird sites throughout the hemisphere. There are currently 40 reserves in the WHSRN network. GSL met the criterion for hemispheric reserve designation by supporting at least 500,000 shorebirds annually or 30 percent of the world population of an individual species. This is the highest designation within the WHSRN system. The designation highlights GSL's importance as a migration corridor line for millions of shorebirds. GSL is a significant refueling (feeding) station for shorebirds and, linked with other critical migration sites, forms a chain of such sites from northern breeding grounds in the Canadian Arctic to wintering places on remote coasts and wetlands of South America.

One reason cited for designation as a Hemispheric Reserve is that the 500,000 Wilson's phalaropes known to occur here represent the world's largest known concentration of the species. Wilson's phalaropes fly over 70 hours during their migration. These shorebirds nearly double in weight while feeding at GSL, storing the fat needed for fuel for their long flight.

## Other Notable Species

Over 75 percent of the western population of Tundra swans and 25 percent of the continental Pintail population utilize the GSL area. The annual production of breeding waterfowl from the marshes adjacent to the lake is estimated to exceed 750,000 birds.

The largest nesting population of California gulls in the world is located on the lake and its environs. North America's largest staging concentrations of American avocets, Black-necked stilts, and Eared grebes occur at GSL, and the largest breeding population of White-faced ibis occurs in the wetlands around the lake. These are only a few examples of the importance of the lake system in terms of bird use and local, national and international recognition as an important bird area.

The aquaculture industry has spotlighted GSL due to the profitable brine shrimping industry. Brine shrimp *(Artemia*) are harvested, marketed and utilized on five continents. The GSL harvest provides a significant quantity of high quality brine shrimp cysts (also known as eggs) to the international market. Brine shrimp cysts and their nauplii (larval brine shrimp) provide the live feed and protein for marine finfish and crustacean hatcheries around the world. The aquaculture industry is rapidly becoming a primary food source for humans.

## Aquatic Biology

GSL aquatic biology has adapted to various saline conditions of GSL ecosystems. The interactions and relationships of the species can be complicated by environmental conditions which are constantly changing in this terminal basin lake. Salinity is a very important factor. The lake has differing characteristics in each of its main bays, but the significant differences are seen contrasting the north arm to the rest of the lake.

The north arm receives limited freshwater inflow relative to the rest of the lake. The northern railroad causeway constructed between Promontory Point and Lakeside effectively separated Gunnison Bay from Gilbert Bay. The salinity of the north arm is significantly higher than the rest of the lake, and is currently close to saturation of sodium chloride. Currently there are six known algal species in this arm. There are few functioning brine shrimp populations in the north arm, and none of significance. Brine shrimp and cysts are washed in from the south arm, but are thought to soon perish due to high salinities. The cysts may persist longer, but may not hatch and grow to adults for the same reason. There may be local sites where freshwater springs discharge into the north arm that allow a small area of the bay to sustain brine shrimp populations because the salinity is locally favorable. As salinities vary, brine shrimp population abundance will change. Relative to the vigorous biota of the south arm, the north arm is comparatively depopulate.

The south arm, Farmington, Ogden and Bear River Bays receive nutrient input from drainages of the GSL watershed. Nutrient data are available for some of these drainages, but the sampling points are located upstream from the freshwater marshes surrounding the lake. The cycling and discharge of the nutrients from these marshes to the lake has not been quantified at this time. The nutrients in the lake water are utilized by algae and bacteria. There are more species of algae and bacteria present in these three bays of the lake than in the very saline north arm. The numbers of species present and their abundance fluctuate with lake salinity.

Algal production in the lake is, however, nitrogen limited (Stephens and Gillespie, 1976 and Wurtsbaugh, 1988), but Wurtsbaugh (1988) found that species (cyanobacteria) that can fix atmospheric $N_2$ and thus remove nitrogen limitation were limited by phosphorous. Both nitrogen and phosphorous are consequently of importance in regulating algal growth in GSL.

The primary consumers of the bacteria and algae are brine shrimp and two species of brine flies. The biomass of these organisms is significant. Brine shrimp and their eggs are eaten by birds and commercially harvested by humans. Brine flies are eaten by birds and other species in their various life stages. Dead shrimp, flies, algae, other organisms and the waste products from all, in return, are recycled through the system by decomposers as base nutrients.

### Bacteria and Algae

There are many species of bacteria that inhabit the waters of GSL. Often, these organisms assist in the decomposition of

dead algae, animals and organic wastes entering the lake by stream flow and wind. It was reported in 1966 by Flowers and Evans that GSL hosts eleven species of bacteria that tolerate moderate to high levels of dissolved salt concentrations. The north arm of the lake supports only two known genera of bacteria, *Halobacterium* and *Halococcus*, which are extreme halophiles present in numbers from 1,000,000 to 100,000,000 bacteria per milliliter. A pigment found in these bacteria gives the water in this portion of the lake a rose-purple hue.

Relative to a freshwater lake, there are few species of bacteria and algae that exist in the hypersaline waters of GSL. However, these organisms have the potential under favorable conditions to exist in great numbers and account for a significant amount of biomass. A taxonomic study of the algal flora of the lake was done between November 1975 and July 1978. The flora consisted of four blue-green algae, seven green algae, one dinoflagellate and 17 diatoms species (Felix and Rushforth, 1979). Two species of green algae, *Dunaliella viridis* and *Dunaliella salina* occur in the lake. During the winter months when there are no brine shrimp, these species typically thrive and the lake has a green hue. After brine shrimp populations are established by spring hatching, these species are grazed off. Brine shrimp population numbers cycle over the course of the summer. Low numbers of brine shrimp allow these species to rebound and the lake can again have a green hue. Both of these species rely upon salinity levels of approximately 13-19 percent to reproduce rapidly (Van Auken and McNulty, 1973). Research is being conducted by Dr. Gary Belovsky of USU and GSLEP to further examine habitat parameters and productivity of lake algae. At the time of this writing, the experiments are still in progress.

Diatom species in the lake seem to be more abundant at specific salinities. An abundance of these species gives the lake water a gold hue. Pennate diatoms are oblong in shape and have a silica covering. These diatoms are too large for brine shrimp nauplii to effectively forage upon them (Stephens, 1998). Brine shrimp numbers seem to diminish when the lake is dominated by diatoms. Laboratory experiments at USU demonstrated die offs of brine shrimp in lake water that contained high numbers of diatoms and low numbers of green algae. Shrimp were observed with black spots on their bodies. This occurs when nutrition is poor and the shrimp subsequently are affected by a virus (Belovsky, 1998).

Research must continue to understand the dynamics of algal populations in the lake and how brine shrimp populations relate to the changes in salinity. Brine shrimp populations diminish when salinities are low and evidence thus far suggests that forage is a significant cause. The current salinity levels of the north arm are too high for many species of algae. In a 1975-78 study which found 29 species of algae living in the lake, the authors reported only two in the north arm. “The findings of (their) study reveal that significant alterations have occurred in the algal flora of the GSL since the construction of the Southern Pacific Railroad Causeway (northern railroad causeway). The migration of dissolved minerals from the south arm into the north arm has reduced the salinity in the southern areas of the lake to the point where viable diatom flora and species of algae previously unknown to the lake have become established. Also the

abundance and frequency of occurrence of previous reported algal species has been significantly altered" (Felix and Rushforth, 1979).

## Brine Shrimp

Brine shrimp (*Artemia franciscana*) are found in all portions of GSL. Their occurrence is related to salinity levels and other environmental conditions. The annual life cycle of brine shrimp begins in early spring. Freshwater inflows to the lake from snowmelt and increasing water temperatures initiate egg (cyst) hatching in late February or early March. Hatching peaks in March or early April. Decreasing lake water salinity from freshwater inflow is an important mechanism in the hatching process. The cysts survive the winter in a semi-dehydrated state. When salinities decline, the cysts rehydrate, causing the shell to swell and crack, which allows the nauplii to emerge. As they mature, brine shrimp molt through as many as 15 different stages before they become adults and begin reproducing.

Brine shrimp reproduce by two methods. During the spring and summer many females give birth to live young that are hatched from eggs within their bodies. The other reproductive mechanism involves the formation of hard-walled eggs (cysts) which are cast into the water by the female. These cysts must then go through a period of dormancy before they hatch. Both of these mechanisms occur throughout the summer, although the birth of live young is more prevalent. In the fall, factors such as the lack of quality food, declining water temperature, decreasing day length and increasing salinity trigger the females to start producing primarily cysts. As many as three generations of shrimp may be produced in GSL during a single growing season. When water temperatures decline below 5° C (42° F), live brine shrimp perish. No adult brine shrimp survive the winter. The population is restarted from the cysts which persisted over winter either in or on the water or deposited on the beaches. As the lake rises in the spring due to inflow, some of the cysts which washed up on the shore during the winter may end up back in the lake.

Commercial harvesting of brine shrimp began in 1950 when adult brine shrimp were harvested for tropical fish food. Several years afterward, cysts were first harvested because they could be dried, packaged, and stored for long periods of time. The eggs could then be hatched as needed. Presently, only cysts are targeted by the harvest operations but there is a small market for the adult brine shrimp bycatch. Most of the harvested cysts are used as hatch out feeds in the aquaculture of shrimp and fish which are reared for human consumption.

## Brine Flies

Often considered "noxious and insidious creatures" (Rawley et al., 1974) brine flies are actually harmless, do not bite or transmit disease and are a very important part of the overall ecology of GSL. Brine flies are the primary food source for many species of animals, spiders and birds living around the shores of the lake. A source of amazement is their sheer numbers, reported to be over 370 million flies per mile of sandy beach, for a total of over 110 billion flies plus 10 billion pupae on approximately 300 miles of beaches around GSL.

Brine fly abundance is variable from year to year, and depends upon changes in water chemistry and other environmental

conditions. The lake's rise in the 1980s probably resulted in an enormous supply of brine flies when the bullrush was inundated and new pupation sites appeared. Wind direction and velocity seem to have a direct affect on their distribution. Brine fly numbers peak during July and August, and decrease as temperatures begin to drop (Vorhies, 1917).

There are two species of brine flies, *Ephydra gracilis* and the smallest and most abundant, *Ephydra hians*, the alkali fly. Brine flies play an essential role in converting organic material entering the lake into food for wildlife living along the lake's shoreline. By removing over 120,000 tons of organic matter each year from GSL, brine flies consume great quantities of algae, bacteria and organic refuse from brine shrimp and their own life processes. It would require a 78,000,000 gallon per day waste water treatment facility about the size of the Salt Lake City municipal treatment plant to remove this much organic waste from the lake. According to biology professor Dr. Robert N. Winget, "Without brine flies or additional water treatment, lake waters would become cloudy and foul smelling, sands would be clogged with algae and decomposing organic materials, and wild animals of the lake area would be starving."

The life cycle of the brine fly consists of four stages, egg, larva, pupa and adult. Each female lays approximately 75 eggs on the surface of the water or on floating debris consisting of brine fly pupal casings, dead brine shrimp or cysts. The eggs sink to the bottom of the lake before they hatch into larvae. They obtain oxygen from the water by diffusion, and feed on blue-green algae. They become free swimming after emergence, until they find suitable habitat such as algal bioherms or other stationary objects in shallow areas of the lake on which to pupate. Nearly 10 percent of the lake bottom is covered with algal bioherms (Cohenour, 1966).

Larvae and pupae have been found in water depths of between one and 20 feet, and can obtain oxygen from the water by use of tracheal gills located in a long forked anal tube. During warm weather, the larval stage also may pupate on the surface of the lake on floating masses of algae. The pupal cases split open on the back and fully develop into adult flies. Flies emerging from the bottom of the lake float to the surface in a bubble of air. The life cycle can be completed in 21-30 days, and may extend longer during cooler temperatures. Adult brine flies only live 3-4 days. Brine fly populations begin to expand rapidly in numbers during the first of June, and one or two generations of flies reach maturity each year. The flies survive the winter in immature stages.

## Corixids

Corixids are small predatory aquatic insects that live in and around the edges of GSL. Their preferred habitat is water with salinity less than six percent along rocky shorelines (Belovsky and Mellison, 1998). Their diet includes, but is not limited to, brine shrimp. These insects have the ability to fly and are observed in the main body of the lake.

Wurtsbaugh (1992), working in Farmington Bay during the 1980s, reported that predation by corixids and copepods on brine shrimp may decrease shrimp population densities. This bay has lower salinity than the main body of the lake due to its being diked and

freshwater inputs from the Jordan River. Gliwicz et al., (1995) suggested that similar salinity levels to those observed in Farmington Bay might allow corixids to decrease the brine shrimp population in the south arm of the lake during periods of lower salinity. This has led a brine shrimp harvester to argue that decreasing salinities in the south arm of the lake has led to a decline in brine shrimp populations.

Belovsky and Mellison (1998) have conducted experiments on predation by corixids on brine shrimp. This information, when combined with the corixid densities in the lake reported by Stephens (1998), indicated that corixid predation rate was 1-2 orders of magnitude less than the brine shrimp population growth rate and has negligible impact on the brine shrimp population in the south arm.

Research findings from Farmington Bay (Wurtsbaugh, 1992) are unlikely to apply to the south arm of the lake due to substantially different limnological conditions. If salinity in the south arm remains higher than six percent, conditions for corixids will be poor and their impact on brine shrimp will be negligible. Wurtsbaugh now considers corixid predation unable to decrease brine shrimp populations in the south arm without dramatic declines in salinity. Furthermore, Wurtsbaugh now considers that brine shrimp in Farmington Bay may have been reduced during his study by other factors (e.g. lack of abundance of high nutrition foods for brine shrimp) that were not examined (Belovsky, 1998).

If corixid numbers were to increase to the point of decreasing the shrimp population, there is no known remedy (e.g., insecticides) that would be environmentally acceptable. Current knowledge suggests that corixids do not limit the brine shrimp population in the lake and sampling programs will continue to monitor corixid abundance in the lake as salinity varies.

## Fish

The current salinities of the north and south arms of GSL are too saline to support fishes. In shallow water areas near freshwater inflows, fish are also important—mostly carp, but sometimes Utah chub. (BRMBR, unpub. and SRC, 1999c) During high lake elevation cycles, the fishery has been known to persist for several years concurrently. Also, Weber River fish may enter GSL during high lake levels. Both of these bays receive substantial freshwater inputs from the Bear River and the Jordan River, respectively.

During the spring runoff period, fish are carried out into Bear River Bay from the adjacent freshwater marshes and waterways. In addition to carp, the Willard Spur portion of the Bear River now have a population of Gizzard shad, an introduced forage fish to Willard Bay Reservoir, which could have escaped into the Spur. This added fish population may be partly responsible for the increased number of fall staging American white pelicans and other fish eating birds at GSL in recent years. The salinity of this bay is very low. A tongue of saline water flows into the bay through IMC Kalium Ogden Corp.'s (formerly Great Salt Lake Minerals) causeway. This layer of salt water is usually found along the bottom of the bay, and its presence and depth is influenced by south winds and the amount of inflow from the Bear River. There is a layer of fresher water on top

of the saline layer. This freshwater can sustain fish populations over time. Fish species in the marshes around the lake have not been extensively studied. Piscivorous bird species such as American white pelicans, Western grebes and Double-crested cormorants use the bay as a foraging area. A strong south wind has the ability to push saline water from the south side of the causeway up into the bay, causing significant fish kills at times.

These fish may be washed out of Bear River Bay into Gilbert Bay of GSL. Dead fish can be preserved to a degree in the saltwater, and are transported around the lake surface by winds and water currents. Observations of these fish in the main body of the lake and/or on the beaches of Fremont, Antelope and other islands leads some people to the assumption there are live fish in the main body of the lake.

Farmington Bay tends to be more saline than Bear River Bay. Salinity is often at 3.5 percent, which is too saline to support freshwater species of fish. The margins of the bay adjacent to the freshwater marsh outflows are sometimes fresh enough to sustain temporary populations of fish and the birds that eat them. However the winds frequently mix the water to the point that the fish cannot survive. Occasionally some fish wash out of Farmington Bay through the Davis County Causeway into the main lake. This phenomenon is not as common as fish from Bear River Bay, because the populations of fish in Farmington Bay are rarely as abundant.

There are times when layers of freshwater may be temporarily found on the surface and periphery of Gilbert Bay and may support fish. When lake levels rose in the mid-1980s, salinities declined to a point allowing fish to exist in shallow areas around the edges of the lake.

## Terrestrial Biology

### Plants

A great deal of work concerning plant life on the shores of the lake has been conducted by various investigators. (Flowers and Evans, 1966). GSL and its environs have a unique diversity of flora, due to the interface between fresh and saline marshes and soils. Halophytic species are found along and adjacent to the beaches of GSL. Freshwater from streams, drainage ditches and springs leaches some of the salt from the soils near the lake, and allows a greater diversity of plant species in some areas. Such areas are quite extensive in the deltas of the Jordan, Weber, and Bear Rivers, and smaller in other areas due to springs or seepage areas.

Playas are low flat depressions in the valley floor formed by bottom currents of ancient Lake Bonneville in its last stages of recession. The west desert is a vast complex of playas laced with irregular bars and local depressions. Salt-tolerant species found on GSL beaches are also found in some playas, depending upon soils, salt gradients and successional stage. Saline plains or uplands extend beyond the playas and beaches around the lake up to the bases of the mountains. The flora is very diverse and includes herbs and smaller scrubs. Their frequency and location depend on the character of the soil surface and rainfall. Slight depressions usually collect water in the

spring and support localized changes in plant life.

Dunes are formed along the eastern shores of the lake and on the plains and foothills bordering the salt desert. Dunes near the lake are composed of white calcareous oolitic sand formed around mineral particles and fecal material. Beach flora is distinct in some areas but in others it is mixed. Vegetation is usually restricted to the upper edge of the shoreline where wave action is less and flooding by brine laden waters is limited in frequency. Mudflats are a special aquatic site and provide important habitat for some wildlife species, such as the Snowy plover, Willet and Long-billed curlew. These areas support pickleweed along the shores of the lake, an important fall and winter forage for geese and other waterfowl.

Vegetation on GSL islands is variable, and ranges from no vegetation to broad diversity on Antelope and Stansbury Islands. Some islands are mere sand bars with little vegetation or cover, some have a considerable amount of vegetation including desert shrubs, and others are quite rocky and devoid of vegetation.

The eastern shoreline of the lake is dominated by wetlands. This narrow strip of vegetation combined with shallow water is important habitat for wildlife and millions of waterfowl, shorebirds and migratory birds. Relatively small changes in lake level inundate or expose large areas of shoreline so lakeshore flora are characterized by multiple successions.

Lake level fluctuations and the shallow gradient of the lake bottom together have a profound affect on the flora and fauna found in this zone of influence. This natural phenomena is critical to maintaining the habitat requirements of many species of birds which inhabit the lake. This mechanism (lake level fluctuation) must be present to maintain this dynamic system.

Around the shores and private lands at the north end of the lake there are extensive stands of sagebrush and this is an important winter grazing area for domestic sheep and deer. Browse-type vegetation located in the Promontory Mountains includes Mountain mahogany, Serviceberry and Bitterbrush, which are valuable to wildlife as food and cover. These areas also have juniper growing on steep and rocky hillsides.

Perennial vegetation consists mainly of grasses and various shrubs such as sagebrush, rabbit brush, greasewood and shadscale, particularly along the west side of the lake. Upland and agricultural areas also provide important wildlife habitat and serve as critical habitat when lake levels are high.

### Reptile and Amphibians

Limited work has been done on the amphibians and reptiles in the GSL ecosystem. Eight species of amphibians, two species of turtles, nine species of lizards and eight species of snakes were identified in the biological resource inventory and study at the request of the Utah Legislature prior to 1976 (Rawley et al., 1974). Some of these species occur on the islands in the lake. Locations and records of occurrence can be examined in *The Great Salt Lake Biotic System* (Rawley et al., 1974).

### Mammals

A total of 64 species or subspecies of mammals have been identified around the lake and on islands in the main body of the lake. Many of the species are rodents. Other species present include bats, rabbits, porcupines, coyotes, foxes, bobcats, mountain lions and deer. DPR and DWR have established antelope and California bighorn sheep on Antelope Island. Locations and records of occurrence can be examined in *The Great Salt Lake Biotic System* (Rawley et al., 1974).

## Birds

Avifauna associated with the lake and its environs are abundant and diverse. Groups include waterbirds, shorebirds and marsh-associated songbirds. Over 250 different species have been identified. Several million birds use the lake area in spring, summer and fall migration. Some unique winter visitors occur in the area including one of the largest concentrations of Bald eagles in the 48 contiguous United States. The lake is of hemispheric importance to many populations of birds.

### Waterbirds on Great Salt Lake

GSL has extensive populations of colonial waterbirds. These species can be found on the lands or marshes adjacent to the lake, or on the islands and dikes/causeways within the lake. There are three primary habitat types utilized by these birds for nesting locations: upland/shoreline substrates, emergent vegetation and areas of woody vegetation.

During the years of 1997, 1998 and 1999, GSLEP conducted a lake-wide intensive waterbird survey. It was completed by 90 surveyors collecting information from 47 survey sites. The data from this concentrated effort during spring, summer and early fall provides an impressive picture of the ecosystem's importance to waterbirds. The total number of waterbird observations for the three years — 21,275,169. The survey will continue in 2000 and 2001 (DWR, unpublished, and 1997-1998).

#### *Habitat Relationships*

##### *Upland/Shoreline Substrates*

Some examples of ground nesters include California gulls, which nest on islands in the lake and on dikes or causeways that transect the lake. Egg Island and dikes at the IMC Kalium Ogden Corp. operation in Bear River Bay are sites for gull colonies. One of the world's largest nesting colonies of White pelicans occurs on Gunnison Island. This extremely remote island provides security from disturbance and predators. The pelicans fly from the island to forage for fish in the freshwater marshes and reservoirs, then return to bring food to their young. Adult pelicans leave the pod between 18-72 hours. Black-necked stilts and American avocets nest on mudflats and playas around the lake. These sites are adjacent to favored shallow water feeding areas. Snowy plovers select playas with little vegetation around the lake for nesting sites.

##### *Emergent Vegetation*

Birds which select the interface of open water areas and the beginning of the emergent vegetation (such as bulrush species) of the exterior marshes include

White-faced ibis, Franklin gulls and tern species, which are often found together in nesting colonies around the lake. Eared grebes also utilize this habitat type, although they are not necessarily nesting along with the species previously mentioned. The populations of these species are substantial. As lake level fluctuates, the location of the bulrush-open water interface constantly changes. The dynamic of the GSL shoreline helps to maintain pioneering stages in emergent vegetation types which are important in developing habitat edge and vegetation density. It allows for periodic open mudflats and playas important for certain bird species and breeding sites for invertebrates. Changing habitats are the key to wildlife diversity and abundance in GSL ecosystems.

*Woody Vegetation*

There is another group of species which utilize a relatively rare habitat type around the lake. This is woody vegetation in the form of trees and large shrubs. These are usually found along the waterways entering the marshes or planted along dikes and uplands by wildlife managers. All of the trees below lake elevation 4212 were killed by salt water and/or flooding during the mid-1980s. Some of the dead trees still persist and new trees have been planted or have naturally re-established. These woody plants are excellent nesting sites for such species as Great Blue herons, Snowy egrets, Black-crowned night herons and Double-crested cormorants. Other species such as raptors utilize these trees as well.

*Pelagic Areas*

The open or pelagic areas of the lake are very important to many birds. These areas are primarily used for either foraging or resting. Eared grebes and Red-necked phalaropes feed on brine shrimp in the open waters of the lake. Gulls are observed there as well. They feed upon dead brine shrimp and brine flies which collect in windrows (streaks) on open water.

## Waterfowl

GSL is located on the eastern edge of the Pacific Flyway. These corridors are the major routes that populations of birds utilize when migrating north and south. These flyways were defined for administrative considerations primarily, not biological, and are utilized in the analysis of bird banding data. It was discovered that birds typically, although not exclusively, migrate in north-south corridors.

Many species of waterfowl have been documented on and around GSL. Over 75 percent of the western population of Tundra swans utilize the lake as a stopover and foraging area during their migration. As many as 60,000 birds have been observed at peak times. They utilize the large lake areas within state WMAs and the BRMBR. Sago pondweed grows in these units and is a preferred forage. Trumpeter swans also occasionally inhabit the area. USFWS and DWR have transplanted Trumpeter swans here from areas where populations have exceeded the food source as a means to broaden their wintering range across the west.

## Breeding

A number of breeding ducks use marshes around the lake. The nesting habitat types used range from dry upland areas to emergent marshes (Table 6).

Table 6. Waterfowl Breeding

| Species | Breeding pair # |
|---|---|
| Pintail | 2,000 |
| Gadwall | 40,000 |
| Cinnamon teal | 40,000 |
| Mallard | <65,000 |
| Ruddy duck | 15,000 |
| Northern redhead | 20,000 |
| Northern shoveler | 10,000 |
| Canada geese | 2,000 |

The total number of individuals is double the breeding pair number.

## Migration

Waterfowl that are produced elsewhere, typically north of Utah, use marshes and GSL as a stopover point during their migration. Up to five million waterfowl migrate through Utah each year. Large numbers of green-winged teal and pintail use the lake each summer as a key molting area. They fly from other areas and use the large open water portion of the lake for security and foraging. During the waterfowl molt, the birds are flightless for a 3-4 week period. Pintail numbers in late summer historically reached about 1,000,000 birds. This is approximately 25 percent of the continental population of these birds. In the 1990s, pintail populations using GSL reached about 250,000. Green-wing teal numbers peak at 600,000 during the molting and staging period. Populations of the following species also utilize the lake during migration periods and peak at the following levels:

Table 7. Waterfowl Population Numbers

| Species | Peak Population |
|---|---|
| Gadwall | 100,000 |
| Cinnamon teal | 80,000 |
| Mallard | 500,000 |
| Ruddy duck | 60,000 |
| Canada geese | 50,000 |
| Northern redhead | 150,000 |
| Canvasback | 50,000 |
| Northern shovelers | 100,000 |

From 7,000 to 11,000 Canada geese annually molt along the west side of Bear River Bay.

Wintering populations of waterfowl are dependent upon habitat and climatic conditions, which change yearly. The amount of water which is not frozen and the availability of food are the primary factors governing abundance of birds during the winter. If the winter is severe and most of the marshes are frozen over and relatively deep snows cover the ground, birds migrate south where more favorable conditions are encountered. Mid-winter numbers of ducks range from 10,000-150,000, depending upon the weather.

DWR participates with other states and USFWS in the management of migrating waterfowl. Management of birds that can move in one day from state to state or even between countries require coordinated management. Utah conducts several bird surveys each year to determine population numbers. These counts are coordinated with other states so a continental population can be

determined. For example, all states conduct mid-winter surveys between January 1-15 to establish wintering population data (Table 7).

## *Habitat Relationships*

There are five major habitat types around the lake that are used by waterfowl species.

### *Uplands*

This habitat is found at slightly higher levels than adjacent marshes, and is usually characterized by dry ground and species of grasses, forbs and shrubs that favor this condition. Uplands are the most limited types of habitat around the lake. These are the areas that are best suited to development, farming and other activities of humans. Many waterfowl species prefer to nest in upland sites, then lead their broods to the marshes to rear them.

### *Freshwater Marsh*

There are approximately 400,000 acres of freshwater marsh wetlands around the lake, principally on the east side. The major surface water inflows to the lake run through these areas. Many impoundments have been constructed by DWR, USFWS and private land owners which include duck clubs and the wetlands mitigation sites of KUC and SLCIA. The Nature Conservancy (TNC) and the Utah Reclamation Mitigation and Conservation Commission (URMCC) also own emergent marsh wetlands. These areas are principally impounded water which support plants including bulrush and cattail. Other land types associated with this habitat include small ponds found within the emergent vegetation and large bodies of water where depth precludes the establishment of these species. Dikes and small islands are also found in these marshes. They are particularly important as nesting and resting sites because, as water levels change, they usually stay dry.

### *Mudflats and Playas*

This major habitat type around the lake is characterized by a very low gradient. As the lake level fluctuates these areas become inundated and then dry out. The water levels can change due to runoff or winds. The lake is so wide and shallow that, as the wind blows across it, water is pushed to the windward side increasing water levels one foot or more due to this tide-like phenomenon. Precipitation or snow melt can also fill low spots in these areas, creating ephemeral pools which are excellent sites for invertebrates. The vegetation on mudflats and playas is often sparse and composed of plant species that are tolerant to high salinities. These include salt grass and pickleweed. Mudflats and playas are important to waterfowl for feeding and resting. Lack of vegetation provides visual security from predators.

### *Brackish-Water*

These areas are located where the freshwater from the marshes flows into the saline water of GSL. The resultant mixing of the waters provides a range of salinities that allow a diverse groups of plants, invertebrates and sometimes fishes to exist. Water depths are often shallow and birds use these areas extensively for feeding.

### *Open Water or Pelagic*

The main area of the lake provides this habitat type. When the surface water is

relatively calm, huge numbers of waterfowl raft in these areas. Isolation from disturbance makes these open water areas attractive to birds. Open water areas also provide important foraging habitat for birds which eat brine shrimp, brine shrimp eggs, brine flies and algae. Brine flies are found on pieces of debris, vegetation, and brine shrimp cysts floating on the lake surface. Huge flocks of green-winged teal, Goldeneyes and Northern shovelers have been observed on the lake, presumably feeding on these resources, however research needs to document this information. During the winter there are other species of maritime waterfowl that are occasionally observed on these expansive open waters. These species include Oldsquaws and Scoters. Gulls and phalaropes also use open water areas.

## Shorebirds

GSL has one of the largest shorebird concentrations in the world. Over 35 species of shorebirds are found in the Western Hemisphere (Sorensen, 1997). Many of these visit GSL each year and commonly include American avocet, Black-necked stilt and Killdeer.

Many of these birds undertake extraordinary migrations with some birds traveling up to 2,000-3,000 miles. Over 50 percent of the world population of Wilson's phalaropes (500,000), the largest staging population in the world, depends on GSL. The largest population of American avocets (250,000) and Black-necked stilts (65,000) in the Pacific flyway, and over 10 percent of all Red-necked phalaropes (280,000) stop over on GSL. The lake also hosts the world's largest assemblage of Snowy plovers (10,000), and the only inland staging area for Marbled godwits (30,000) in the interior of the United States. Observations of over 30,000 Long-billed dowitchers have been made on a single occasion.

The GSLEP has cooperated in the development of a national shorebird management plan. A local shorebird plan is being developed to help guide management of these birds around the lake. A working group comprised of government and non-government stakeholders is developing a GSL Shorebird Plan. This effort complements the national shorebird planning effort but focuses on the unique conditions and needs of GSL shorebird habitats and conservation.

## Habitat Relationships

The most significant aspect of the GSL ecosystems is the great diversity of habitats created from the integration or close association of fresh and salt water systems which create a fluctuating "mosaic" of land forms, vegetative cover, water and salinity. Several habitat types, natural and human-made, are described below to illustrate the importance of each micro-habitat. Management and conservation efforts must consider each habitat type and the species that frequent these areas.

### *Estuaries*

Fresh and salt water interfaces are created where freshwater enters directly into the lake such as the outflows of several small streams along the east shore. These areas provide important foraging areas for breeding, brooding, and staging shorebirds. These areas also remain ice-free in winter and provide habitat for waterfowl.

### *Playas/Ephemeral Pools*

Salt playas, mudflats and other lake interfaces occur at numerous locations throughout the extremely shallow, low gradient GSL Basin. These environments shift seasonally and with lake level fluctuations. These areas are critical to Snowy plovers for nesting and provide foraging and staging areas for numerous shorebirds, including tens of thousands of Avocets and Stilts. The associated shoreline supports a robust population of brine flies which is a significant avian food source. The transitory nature of this habitat type introduces a constant dynamic state so that emergent vegetative stands are constantly shifting between early and late seral stages as the water levels advance and recede. A rich mosaic pattern of habitat types is the result. Some examples include Farmington Bay, Howard Slough and the areas west of existing WMAs and TNC's Layton Wetlands Preserve. There are numerous ephemeral pools that are associated with the mudflats and playas. They are resultant of slight changes in topography and precipitation, overland flow (runoff), wind tides from the main lake and receding lake levels. Small pools create critical habitats for waterfowl and shorebirds and create unique places for food production for invertebrates and vegetation species.

### *Salinity Variations*

Salinity varies around the main body of the lake due to geographic location, basin configuration, geology and the presence of human-made structures. A variety of plants (halophytes) and animals (halophile) including invertebrates are dependent on these differing saline habitats. Each species has an optimum range of preferred salinity levels, and this wide spectrum of salinities provides unique and critical habitat for wildlife. Brine shrimp play a significant role in the GSL ecosystems and, along with brine flies, are the keystone species supporting many of the water and shorebird species that frequent the lake. A primary reason for the hemispherically important bird numbers at GSL is the lake's capacity to produce millions of pounds of easily foraged protein at the appropriate times for staging and molting migratory birds.

Generally, the north arm (Gunnison Bay) is extremely saline and only supports brine shrimp when the lake is at very high elevations. The north and west shorelines of the lake are important to wildlife there. The west and south shores are moderately saline, and support brine shrimp at high to average lake elevations. The northeast, east and southeast sides of the lake are less saline and support brine shrimp and other invertebrates during average and lower lake elevation years. These open lake and littoral zones are exceptionally important to phalaropes, Franklin and California gulls and Eared grebes. The east shore of the lake has many productive habitats due to the freshwater deltas of the Jordan, Weber and Bear Rivers, and numerous smaller Wasatch Front streams. The water from all these drainages has been totally or partially diverted through natural or managed wetlands adjacent to the lake. The historic Jordan and the Weber River Deltas have been abandoned and receive little or no natural flow. These are very productive areas for waterfowl, colonial nesters and many shorebirds, including Dowitchers, Yellowlegs, Godwits, Avocets and Stilts.

During the high lake years of the 1980s, the north arm provided the only substantial habitat for pelagically active

Eared-grebes, Wilson's and Red-necked phalaropes that occurred within the GSL ecosystem. This condition occurred because of the reduced salinity which, in turn, improved conditions for brine shrimp and brine fly survival.

## Great Salt Lake Wetlands

GSL wetlands consist of a mosaic of habitat types including emergent marshes, playas and wet meadows. Wetlands around the lake are unique in North America because they cover a large expanse of inland alkaline and saline wetlands located in a cold desert. Approximately 400,000 acres of wetlands (at 4202 lake level) exist near the shores of GSL, which represents almost 75 percent of all the wetlands in Utah. GSL wetlands provide a variety of functions, including wildlife habitat, water quality enhancement, aquifer discharge, temporary water storage and nutrient cycling.

### *Managed Wetlands*

Managed wetlands have created unique habitats with dikes, levies, headgate systems and diversion structures. These systems enhance the opportunities for active management by changing water depths, temperature and water dispersion patterns and by controlling nutrient flows over time. These managed wetland areas accommodate seasonal use and the needs of migrating and breeding water birds. Significant production of waterfowl also occurs in these areas.

## Avian Surveys, Studies and Information

GSL is the largest permanent saline lake in the U.S. and is a critical habitat area for birds. There are many bird surveys conducted on and around GSL to answer specific questions such as total numbers present, peak season use, species use and habitat relationships. A waterbird survey conducted by DWR GSLEP is the most extensive to date. Approximately 90 volunteers assisted with the count. It began in 1997 and is projected to continue until 2001. The count examines total number of waterbirds over time and relates this data to habitats.

In addition, there is an enormous amount of information and research (published and non-published) available on the flora and fauna of GSL. A literature search has been completed by USU and GSLEP. The project searched for research papers on brine shrimp in natural systems, limnology of saline lakes, avifauna ecology of hypersaline lakes in the Western Hemisphere and research on GSL. A bibliography is will be available at the DNR Bookstore.

The Utah Natural Heritage Program is a central repository for information about Utah's biodiversity including animal and plant communities. This program was initiated by TNC in 1988. The program was transferred to the state in 1991 and is currently partially funded by DWR. The program's mission is to collect information about Utah species and plant communities in a standardized and easily retrievable way and provide this information for natural resource management decision-makers.

The Utah GAP analysis program is comprised of a geographic information system (GIS) that includes map layers of habitat types, vegetation, wildlife distribution and other resources. This information can be utilized to investigate spatial relationships of resources and to track changes or trends in wildlife distribution and habitat utilization. Many master's and doctoral dissertations have been completed on the ecology of GSL and are kept at the universities where the research was originally funded. These publications will be cited in the bibliography prepared by DWR and USU. Recently completed and ongoing research includes the following efforts:

### Periodic Waterfowl Surveys on State WMAs (DWR)

Pacific Flyway Shorebird Project (Point Reyes Bird Observatory)
Bear River Migratory Bird Refuge Bird Abundance Surveys (USFWS)
Canada Goose Banding (DWR)
Pacific Flyway Duck Banding (DWR)
Great Salt Lake Botulism Study (USU)
Mechanisms for coexistence of two swan species at varying spatial scales (USU)
Interactive pathways in wetland ecosystems (USU)
Restoring breeding bird population to Bear River Migratory Bird Refuge (USU)
Brine Shrimp Population Dynamics (USU)
Brine Shrimp Populations and Lake Limnology (DWR & USGS)
Salinity Model/Patterns in the GSL (USGS, DNR, Tooele County)
Bioenergetics of the eared grebe (DWR, USU)
Population Status of the eared grebe (DWR)
Water Quality and Contaminant Research (USFWS & FFSL)
Food Chain Ecology on the Great Salt Lake (USU)
Mid-Winter Eagle Count
Snowy Plover Surveys (1996-Weekly/Summer; American Birding Association)
Spatial/Temporal Avian Census of the Great Salt Lake (DWR and cooperators)
Brine Shrimp Population and Harvest Census (DWR)
Brine Shrimp Ecology of Great Salt Lake Beaches (DWR)

A significant local effort is the National Audubon Society's *Feasibility Study for the South Shore Wetlands Ecological Reserve of the Great Salt Lake* (1995). This was an investigation of the potential of restoring the natural inflow of freshwater to the prehistoric river channel and delta of the Jordan River. The results of this study indicated that a state of the art ecosystem wetland habitat restoration effort would have a high likelihood of success. This is one example of an effort focusing on improving habitat for waterfowl, shorebirds and other water birds.

## Research

As mentioned previously, in July 1996, DWR formed GSLEP. The purpose of this project is to exclusively dedicate personnel to research and management of the GSL ecosystems, focusing on the relationships of aquatic species of the lake to resident and migratory birds. As implementation of the project began, it became apparent that no one had previously attempted to manage a naturally occurring brine shrimp

population or the bird populations that rely upon it. Therefore, the methodologies and techniques had to be developed for the first time to gain the necessary data.

GSLEP is staffed by the project leader, an aquatic biologist, a wildlife biologist, a wildlife technician and various biological aides hired seasonally. Law enforcement officers conduct field operations during the harvesting season and at other times as necessary to regulate the brine shrimp harvesters.

To address the broad ecological questions necessary for management of the ecosystem, DWR has contracted with a number of researchers. Dr. Gary Belovsky of the Department of Fisheries and Wildlife and Ecology Center at USU was contracted to research factors influencing the dynamics of the brine shrimp population and develop a population model. A preliminary model was developed using available data from the lake and pertinent literature. Model components included primary and secondary production in the lake as it influences the brine shrimp population dynamics and standing crop of shrimp, rate of shrimp consumption by harvesters and birds and the cycling of nutrients back to the system. Values from the literature were used in place of available GSL data when appropriate, however in many instances, no literature values were available for the required parameters. Many of the research endeavors of the GSLEP are targeted at these deficiencies. From the model, annual shrimp production in the lake, amount of forage required by the birds, quantity of cysts harvested and the amount of cysts that are needed to restart the population the following spring can be predicted.

Other brine shrimp related research projects currently underway at USU include determining the overwinter mortality of cysts within the lake, and a study of corixid predation on brine shrimp.

A research project on Eared grebe-brine shrimp interactions is underway. Dr. Michael Conover of USU is the contracted researcher. This research is geared toward understanding their reliance on brine shrimp as a food source. Eared-grebe reliance relates to brine shrimp densities, grebe energetics and other issues.

Dr. Doyle Stephens of USGS has been contracted to conduct field sampling of sites in the south arm of GSL and conduct laboratory analysis of these samples. This information will be input to the management population dynamics model developed by Dr. Belovsky.

In addition to this work, DWR and DFFSL have joined with other cooperators in funding data collection by USGS necessary to refine an existing water and salt balance model which predicts the transport of salts between the north and south arms of the lake (Appendix G). During the GSL planning effort, USGS was contracted to conduct a bathymetric study of the lakebottom topography near the northern railroad causeway culverts.

Dr. Susan Kilham, a noted diatom researcher from Drexel University, Pennsylvania, will be conducting a one-year sabbatical study on diatoms in GSL. It is hoped that this research will provide insights into the factors controlling algal community shifts within the lake.

GSLEP personnel are also conducting research that will assist with management directly or enable future inputs to the brine shrimp model. Some of the objectives of project research include:

- Conducting waterbird counts and determining seasonal use.
- Understanding the role of brine shrimp cysts in the diet of wintering ducks.
- Developing sampling techniques to quantify floating cyst streaks.
- Learning more about brine shrimp biology in the lake.
- Understanding the relevance of salinity to cyst characteristics.
- Understanding brine shrimp and algal population changes as they relate to salinity.
- Understanding brine shrimp cyst mortality in the lake over time.

An avian census program has been conducted for two years with the assistance of many volunteers. The objective of this research is to quantify timing and magnitude of bird use in various habitats around the south arm of the lake, Bear River Bay and Farmington Bay. This information will be critical input to the brine shrimp population model in understanding the needs of birds as they relate to brine shrimp. Other bird conservation needs will also be addressed. Additional work is underway with bird banding, specific grebe research and conservation planning. A Snowy plover research effort was partially supported by DWR in 1997. Study results indicate that Snowy plover population numbers were relatively unchanged from the initial study.

## Existing Division of Wildlife Resources Management Programs

### Functions of Division of Wildlife Resources and Wildlife Board

DWR has jurisdictional responsibility for all wildlife in the state pursuant to Section 23-15-2 of the Utah Code, which provides;

> "All wildlife within this state, including but not limited to wildlife on public or private land or in public or private waters within this state, shall fall within the jurisdiction of the Division of Wildlife Resources."

The division is "appointed as the trustee and custodian of protected wildlife..." and, subject to the broad policy making authority of the Wildlife Board, the division's responsibilities are to, "protect, propagate, manage, conserve, and distribute protected wildlife throughout the state" (Utah Code 23-14-1(2)).

The Wildlife Board's responsibility is to, "...establish the policies best designed to accomplish the purposes, and fulfill the intent of all laws pertaining to wildlife and the preservation, protection, conservation, perpetuation, introduction, and management of wildlife." The Wildlife Board relies on the division's determinations of fact, and on the recommendations of the Regional Advisory Councils (RACs) established under Section 23-14-2.6 of the Utah Code. Under Utah law, five RACs conduct hearings to collect public input, gather information from division staff, the public and government agencies and make recommendations to the Wildlife Board in an advisory capacity.

On and near GSL, DWR's responsibilities include: research on and management of wildlife species, regulation of hunting, regulation of commercial brine shrimping, management of state WMAs, cooperative management of Antelope Island's large ungulates with DPR, cooperation with USFWS in the management and research of migrating birds and cooperation with non-governmental and other governmental agencies in the conservation of wildlife habitats.

## Great Salt Lake Waterfowl Management Areas

There are eight DWR WMAs on GSL. Six are located along the shoreline of the lake, and include Farmington Bay, Howard Slough, Ogden Bay, Harold Crane, Locomotive Springs and Timpie Springs (Exhibit 1). The others are within 10 miles of the lake and have a direct association with the lake environs. Salt Creek WMA, Bear River Access and Willard Bay are examples. A total of 87,244 acres are intensively managed by DWR. Some acres are managed under cooperative agreements with other state and federal agencies, such as DFFSL and BLM. Utah Code Section 23-21-5 identifies approximately 150,000 additional acres in the lake area which are authorized for administration by DWR for hunting, fishing and wildlife management purposes.

DWR is in the process of developing a habitat management plan for each management area. These plans describe each area, identify capital improvement needs and describe generalized management activities associated with identified goals and objectives.

General management actions include wildlife habitat enhancement through water control, agricultural practices, population monitoring, law enforcement, education and information sharing to support and build an appreciation for wildlife, habitat, wetlands, wildlife management and conservation.

WMAs can be affected by high lake water levels and have many common management issues and concerns. Important issues include securing future water supplies, access management, balancing the needs of user groups, funding to operate and maintain facilities, urban changes in the GSL flood plain, flooding of lower tributaries, water pollution, siltation and invasion of plant species such as Phragmites, Tamarisk and Purple loosestrife.

Acreages of different types of habitats were extracted from "*Evaluation of Existing Wetland Habitats in Utah*" (Jensen, 1974). The lake elevation was 4201 when this study was completed. The intent of stating acreages is to give the reader a sense of marsh habitat relationships. These figures have changed over time due to lake changes.

For ATV use and other WMA restrictions, refer to the current waterfowl hunting proclamation.

### *Farmington Bay Waterfowl Management Area*

Farmington Bay WMA is located west of Interstate 15 between Centerville and Farmington. This area can easily be accessed from Glovers Lane west of the interstate and south along the access road. Duck clubs, city, county and private property outline the perimeter of the WMA. Farmington Bay is one of the

most popular waterfowl hunting areas in Utah and also is an outstanding birding area. It is unique in that it provides important wetland and wildlife habitat based recreation close to an urban area. This 17,916 acre management area is one of the best places to observe the freshwater interface with GSL. The Jordan River is the primary water source for Farmington Bay. This area is managed primarily to provide habitat for water-dependent birds.

Farmington Bay has sufficient water rights. To protect their water rights from the potential of non-use forfeiture during the flood years, DWR filed Requests for "Extension of Time in Which to Submit Proof of Appropriation" on their uncertificated water rights and "Non-Use Applications" on their certificated water rights. Reestablishment of those water rights requires the submission of Proof of Appropriation for the uncertificated water rights and Proof of Resumption of Use for the certificated water rights by early 2000. DWR is currently preparing those proofs for submission to the State Engineer using funding obtained through the "Habitat Authorization" process.

The Farmington Bay WMA was constructed in 1935 to provide habitat for nesting and migratory waterfowl. It includes 12,000 acres impounded by dikes and another 15,000 acres of natural estuary wetlands. Habitat types include:

| | |
|---|---|
| 4,301 acres open water | 6,277 acres marsh |
| 6,174 acres mudflats | 600 acres uplands |

Farmington Bay WMA provides opportunities for hunting, bird watching, photography, nature study, hiking, biking and air boating. Currently, DWR is pursuing funding for enhanced visitor use development, which includes a visitor center on the north end of the management area to improve interpretive and education efforts.

WMA dikes and water control structures around GSL are impacted by natural lake level fluctuations. The outer dikes have top elevations varying between 4204 and 4208. At lake level elevations above 4204, the WMA loses the ability to impound shallow water. Farmington Bay dikes were designed to impound and spread shallow water at a lake level elevation of 4198. Lake level elevations higher than 4198 reduce management efficiency and increase loss of habitat units. At 4206, nearly 80 percent of this WMA is inundated, and above 4210 all created habitats are lost. Flooding impacts to the interior marshes occur incrementally between 4201 and 4212.

Birds relocate when lake level fluctuations inundate suitable habitat areas around GSL. In response to this natural dynamic, DWR has designed portable structures for walk ways, restrooms and office facilities. Approximately one million dollars was required to repair damages from the 1980s flooding event. The most significant management issue at Farmington Bay is future water quality and supply. Other important issues include providing additional access and balancing diverse user groups. Expansion of the Farmington Bay WMA has been discussed, but there appears to be a limited number of willing sellers from which to acquire additional property.

### *Harold Crane Waterfowl Management Area*

Harold Crane WMA is located on the south-west corner of Willard Bay

Reservoir, and is approximately 11,300 acres of the following habitat types:

| | |
|---|---|
| 2,905 acres open water | 3,805 acres marsh |
| 3,210 acres mudflats | 1,380 acres uplands |

According to engineering data, lake flooding over the dikes occurs at elevations between 4207-4210. However, in the spring of 1999, some flooding damage did occur at locations below 4207.

This area was constructed in 1964 as mitigation for wetlands lost due to the construction of Willard Bay Reservoir. Additional lands acquired in 1990 doubled its size. Foot access is permitted between September 1 and March 1. The gate is open to vehicles and small boats during hunting season, but closed to motorized vehicles and boats the rest of the year. The area is closed from March 1 to September 1 during the bird nesting season.

### *Howard Slough Waterfowl Management Area*

This WMA is located two miles west and one mile south of Hooper in Davis County. Howard Slough was established in 1958 to create wetlands from irrigation return flows before they entered the lake. This development was the first major wetland project along GSL in over 20 years and a subsequent 1990 expansion was Utah's first *North American Waterfowl Management Plan* cooperative acquisition. Major redesigning and restoration occurred at this time.

This area includes a total of 3,420 acres of the following habitat types:

| | |
|---|---|
| 600 acres open water | 1,800 acres marsh |
| 631 acres mudflats | 389 acres uplands |

According to engineering data, lake flooding over the dikes occurs at elevations between 4206-4208. However, flooding occurred at points along the dike in the spring of 1999 when lake elevations exceeded 4203.

### *Ogden Bay Waterfowl Management Area*

Ogden Bay WMA is located on the Weber River delta of GSL, and, at over 21,000 acres, is the largest state waterfowl management area in Utah. The northwestern boundaries are indefinite. Land acquisition and development of Ogden Bay WMA started in 1937 with a cooperative project between DWR, Weber County Wildlife Federation, USFWS and the Civilian Conservation Corps. In 1938, following the passage of the *Pittman-Robertson Act*, Ogden Bay became the nation's first Federal Aid to Wildlife restoration project. It is located two miles west and one mile north of Hooper in Davis and Weber Counties. Ogden Bay WMA contains the following habitat types (acreage numbers are estimated):

| | |
|---|---|
| 4,998 acres open water | 4,780 acres marsh |
| 5,182 acres mudflats | 3,800 acres uplands |

Ogden Bay WMA is also known for wildlife-related recreation on GSL. During the production period, March 1 through August 1, approximately 15 miles of dikes are open to non-motorized use. Throughout the rest of the year, 45 miles of dikes are open to non-motorized use. Several air boat ramps and parking areas are available for public use at various lake levels during the hunting season. Ogden Bay WMA has

approximately 70,000 visitors each year, 28,000 of which are waterfowl hunters and the rest are other wildlife enthusiasts. The most popular activities include wildlife watching and waterfowl hunting.

Ogden Bay WMA's wetland resource values are dependent on the water levels of GSL. A series of boat ramps which are useable at various lake levels improve access. Wetland habitat, wildlife use and public recreation opportunities are greatly reduced at high lake level elevations. During the 1980s flooding, wildlife and human use decreased by over 90 percent. Lake level begins to affect Ogden Bay WMA dikes at a lake level elevation of 4203, which occurred in 1998. Other dike elevations range from 4205-4212, with upland areas at an elevation of 4220. More than 80 percent of the area is flooded at a lake elevation of 4211. Flood damages to the diking system were close to $150,000 in the 1980s.

Important issues for Howard Slough and Ogden Bay WMAs include vulnerability to flooding from the Weber River and GSL. Other management issues include additional access for air boats, visitor conflicts, water quality and high levels of sediment entering via the Weber River. The water rights are sufficient since this is one of the oldest WMAs in Utah. Another concern is diminishing agricultural habitat and food sources for White-faced ibis, waterfowl and other agriculturally-dependent species due to residential housing development on the periphery of the management area.

### *Timpie Springs Waterfowl Management Area*

Timpie Springs WMA is located one mile north of I-80 at Rowley Junction, 15 miles northwest of Grantsville in Tooele County. This WMA is comprised of 1,440 acres. The water source is a saline spring which feeds two water impoundments created by 3.5 miles of dike. The salinity of the water source limits the vegetation of the area to salt grass. Waterfowl, waterbirds and shorebirds utilize this area. It is important because there are few significant marshes and sources of fresher water around the southwest quadrant of the lake. Bass and mosquito fish may be found in the springs. There is a half-mile long road that provides access to the area from I-80. This road terminates in a parking lot where there are informational signs. Timpie Springs has approximately 400 annual visitors, of which approximately 300 are waterfowl hunters. Walking access to the area is available all year from the parking lot. Habitat types include:

| | |
|---|---|
| 350 acres open water | 400 acres marsh |
| 390 acres mudflats | 300 acres uplands |

### *Locomotive Springs Waterfowl Management Area*

Locomotive Springs WMA is an isolated, spring-fed wetland located at the north end of GSL, east of Kelton. This 17,317 acre WMA is supported by six springs and provides a much needed oasis for wildlife in the middle of the west desert. Habitat types include the following:

| | |
|---|---|
| 1,370 acres open water | 3,250 acres marsh |
| 9,077 acres mudflats | 1,455 acres uplands |

The Civilian Conservation Corps created the Locomotive Springs WMA in 1931. DWR plans to expand the WMA by 2,600 acres to include protection of playas which are Snowy plover habitat. Wildlife viewing activities include some passerine and scrubland bird species. This WMA is open to public use during waterfowl hunting season, however access is allowed year round at the six springs. Vehicular use is restricted beyond designated parking areas. Bird watching, fishing and primitive camping are allowed year round. The entire WMA is accessible during hunting season. Locomotive Springs receives approximately 6,000 visitors a year, 5,000 of which enjoy hunting and fishing.

The most significant issue facing Locomotive Springs is maintaining water flow from the springs throughout the year. Since the early 1970s the spring flow has declined by 67 percent. This has resulted in diminishing wetlands by 5,000 acres in this WMA. Diminished flows have also resulted in higher salinities in the impounded waters of the marsh which affects vegetation.

## Other Important State-Operated Wildlife Management Areas

Other WMAs located beyond the meander line of GSL provide a variety of different habitat types for many species that depend upon the GSL ecosystem. These areas are directly associated with the lake environs and become critically important when high lake levels inundate otherwise available habitats at lower elevations.

### *Public Shooting Grounds Waterfowl Management Area*

Public Shooting Grounds WMA was perhaps the first area in the nation set aside specifically for hunting when it was established in 1929. It is located 10.5 miles west of Corinne on U-83 and is directly north of BRMBR. This 11,834 acre area includes cold desert upland plant species, extensive wetland vegetation, 11 developed ponds and mudflat areas providing great habitat diversity. Habitat types include:

| | |
|---|---|
| 2,305 acres open water | 4,129 acres marsh |
| 3,675 acres mudflats | 1,455 acres uplands |

This WMA is not accessible without permission except during waterfowl hunting season. Camping is allowed during this time period. No air boats or ATV use is allowed.

### *Bear River Access Wildlife Management Area*

Bear River Access WMA was purchased in 1989 for fisherman access to the Bear River. This WMA is small, only five acres, but includes a parking area and a hardened launch ramp for easy access. The WMA is set in a riparian valley bottom at an elevation of 4220 feet, and is a diverse and productive area for waterfowl and wildlife. Camping, boating and fishing are the primary and popular recreational activities available in this area. Wildlife viewing opportunities include waterfowl during spring and fall, Bald eagles in the winter and a variety of other species.

### *Salt Creek Waterfowl Management Area*

Salt Creek WMA is located eight miles west of Corinne on U-83 then north of Little Mountain. It was established in 1961 and has expanded from 1,389 acres to approximately 5,236 acres. The area provides semi-marsh habitat with open water ponds and extensive wetland vegetation. Elevations range between 4255 and 4270 feet. Upland areas include cold desert plant species. Habitat types in this area include the following:

| | |
|---|---|
| 1,208 acres open water | 1,210 acres marsh |
| 120 acres mudflats | 2,006 acres uplands |

Vehicle access is possible to Comptons Knoll throughout most of the year, but is difficult during winter months. However, all other access points are restricted except during the waterfowl hunting season.

### *Willard Bay Upland Game Wildlife Management Area*

Willard Bay Upland Game WMA is located on the south side of Willard Reservoir, and consists of primarily upland habitat mixed with cultivated food plots. This provides habitat for many species of wildlife, and is particularly ideal for pheasants. Riparian wetland areas in this area are productive and attract a variety of wildlife species. Recreation activities include hunting, dog training and wildlife viewing of waterfowl and songbirds. This WMA contains 1,350 acres and is accessible along the south dike of Willard Bay just west of the south marina entrance.

## State Parks

### *Antelope Island State Park*

AISP is managed by DPR and provides habitat for an unusual array of wildlife. The most visible and well-known of the park's wildlife are bison. The island bison herd, which numbers over 700 after calving season, is one of the largest public herds in the nation. The herd is maintained within a managed carrying capacity via a roundup and sale of surplus animals and limited hunting permits. The sale of bison finances the park's wildlife program.

Pronghorn were reintroduced in 1993 through a cooperative effort between DPR and DWR. A similar cooperative effort resulted in the introduction of bighorn sheep. Antelope Island provides a disease-free environment as it relates to domestic sheep, which is a key consideration for bighorns. A program goal for the island's bighorn herd is to produce a surplus for reintroduction of bighorn sheep to other historic ranges. Mule deer, coyotes, bobcats and badgers as well as numerous small mammals also inhabit Antelope Island.

The island's east shore wetlands are proximal to the mainland marshes and provide additional water bird habitat. The island also provides important upland habitats adjacent to wetlands.

DPR established an independent Wildlife Advisory Committee to review management programs pertaining to range and wildlife issues. Outside research projects have been funded and focus on pronghorn, bighorn sheep and bison genetics. Staff monitors range conditions and trends, herd sizes and composition and assists DWR with

shorebird census projects. Future research will study recreational impacts on wildlife populations.

## Important Habitat Managed by Other Entities

Many areas around the lake are managed for habitat preservation and improvement by other entities such as conservation groups, duck clubs, counties and federal agencies.

### *Bear River Migratory Bird Refuge*

BRMBR is located west of Brigham City in Box Elder County at the mouth of the Bear River. It is the largest national refuge specifically set aside for waterfowl and shorebird management. The Bear River Delta is considered one of the most valuable water bird and wetland areas in Utah. Waterfowl, water birds, migratory birds and wildlife depend on the refuge as an important breeding, wintering and staging area (USFWS, 1993).

The refuge was established in 1928 through an Executive Order by Herbert Hoover and the permission of the State of Utah. Today, BRMBR encompasses approximately 74,000 acres providing contiguous and diverse habitat areas for wildlife. The primary management goals of the refuge include protecting and enhancing habitat to maintain or increase threatened and endangered species, providing suitable production and migration habitat to benefit migratory birds and providing a biologically diverse suite of habitat types in various successional stages to maintain healthy wildlife and fish populations. Secondary management goals include providing opportunities for the public to enjoy wildlife and to better understand their role in the environment and ensuring protection for important archaeological, historical and cultural resources. Over 43 archeological sites have been recorded on the refuge.

A 12-mile driving or hiking tour is open year round and provides an excellent opportunity for wildlife viewing and environmental education. Hunting, trapping and warm water fishing on the main river channel are popular activities available seasonally. Over 40 percent of the refuge is open to waterfowl hunting. A 1990 study, to examine the economic value of the refuge, indicated that 20,000 visitors equates to over $180,000 to the local economy (Piper, 1990).

Water control structures are designed to regulate water flow into several management units to create diverse habitat areas to benefit wildlife. Approximately 18,937 acres of the refuge do not receive water from the Bear River. Water supplies are rarely at optimum levels. Flushing removes excess salts and drawdowns improve some habitat types. During the 1980s, GSL flooding caused over $42 million of flood damage including the loss of the visitor center, dikes, water control structures and roads. The outside dikes are presently at 4208.75 feet, which is a 0.75 foot increase from pre-flooding elevation.

BRMBR completed a *Long Range Water Management Plan* in 1993, to examine existing water management, enhance refuge habitat and improve future water supplies and management for maximum wildlife benefit. Important management concerns include water supply, water quality and disease management. Water shortages are very detrimental to wetlands and wildlife. USFWS would

like to augment natural flows of the Bear River during July and August. A project to supplement these low flows with Willard Bay water was negotiated, but the project was not constructed. Future water development projects on the Bear River are currently under consideration and include plans for the Honeyville area, but there is no authorization for this dam to date. Disease management focuses on botulism outbreaks and attempting to understand ideal conditions by linking losses with water conditions and habitat indicators. Peak avian botulism losses seem to occur during above-average water years,
according to USFWS. Water quality and sediment contamination have been investigated in BRMBR and in proposed acquisition areas. "Soil and water analysis from this study did not identify any toxic constituents, although further sampling of soil, water and fish tissues may be warranted in the Black Slough area to determine the source(s) or extent of DDT contamination," according to the contaminant study of Waddell et al. (1990). Also, salts were present in high levels in both water and sediments.

### *Layton Wetlands Preserve*

Layton Wetlands Preserve is a mosaic of over 2,500 acres of wetlands, playa and upland habitats. It is owned and managed by TNC. An additional 1,000 acres of adjacent property is managed by TNC for URMCC. TNC continues to look for opportunities to protect important wetlands and uplands around GSL.

Management of the preserve is conducted within the context of identifying conservationally important species and communities, identifying stresses or threats to those conservation targets and developing strategies to minimize the stresses or threats. One of the primary conservation strategies outlined in the plan is to allow the dynamics of GSL to act naturally upon the landscape in this undiked area.

To address management issues on the preserve, TNC is also developing visitor management, weed management and community outreach plans. Wetland restoration activities are being conducted on the preserve. Much of the work is accomplished with volunteer help and the assistance of local experts.

### *Inland Sea Shorebird Reserve*

This 3,889 acre reserve was developed by KUC to mitigate for the tailings modernization and expansion project completed in 1998. The reserve provides a large contiguous area for nesting and resting habitat for migratory shorebirds and waterfowl. The Inland Sea Shorebird Reserve is surrounded by private duck clubs, the Gillmor Wildlife Sanctuary and the SLCIA Mitigation Project, all of which provide wildlife habitat. The reserve has three water sources, including Goggin Drain, Lee Creek and the North Point Canal. They circulate brackish water through marshes and mudflats to maximize invertebrate populations as food for visiting birds. A unique sand dune environment exists on state sovereign lands adjacent to the reserve (Neville, 1998).

Once COE approves the mitigation project, which is expected in 2002, KUC plans to allow greater public access. Important issues for the Inland Sea Shorebird Reserve include access to sovereign lands and mosquito abatement practices.

### *Gillmor Wildlife Sanctuary*

The land for the Gillmor Wildlife Sanctuary was donated to the National Audubon Society to help preserve the natural ecosystem of GSL. This 1,425 acre property has a variety of habitat types ranging from open water to playas and upland areas. It is located north of I-80 and west-northwest of the new SLCIA runway on the abandoned delta of the Jordan River. The *Feasibility Study for the South Shore Wetlands Ecological Reserve of the Great Salt Lake* was conducted with URMCC to investigate the possibility of restoration of the natural inflow of freshwater to this old river delta system. The hydrological study and analysis concluded that approximately 2,000 acres of potential wetland habitat could be developed or restored in this area to provide a mosaic of wetland and upland habitats for wildlife.

The goals of the adjacent property owners are compatible in developing a contiguous area of highly productive habitat suitable for breeding, nesting, foraging and resting for a wide range of species. A goal for this area is to acquire water for future improvement of wildlife habitat.

### *Salt Lake City International Airport Mitigation Site*

The SLCIA runway expansion project required mitigation for wet meadow wetlands habitat loss. Most of this mitigation site is surrounded by private property, duck clubs and the Gillmor Wildlife Sanctuary. The mitigation site includes 1,500 acres of wetland habitat. SLCIA authorities plan to focus on increasing shorebird habitat by 70-80 acres by enhancing marginal wetlands and uplands. Issues facing this mitigation project include flooding impacts, changes in water use from agriculture to urban, non-native species invasion and future supplies of freshwater entering the mitigation site.

### *Great Salt Lake Duck Club Properties*

According to the *South Shore Duck Club Study* (Dunstan and Martinson, 1995), 13 duck clubs exist on the south shore of GSL, with more than 16,791 acres managed as wetlands for waterfowl habitat. Many duck clubs also exist along the east and north areas around the lake. Private duck clubs develop additional habitat and actively manage and enhance existing habitat to increase wildlife use for the purpose of waterfowl hunting. Enhanced areas require active management to maintain wetland and wildlife functions. These efforts also improve habitat conditions for a variety of other species and, together with the efforts of adjacent landowners, provide a considerable amount of contiguous habitat for wildlife around GSL. The *South Shore Duck Club Study* conducted between 1994-95, examined the feasibility of a formal protection plan and the possibility of developing public support for these privately owned and managed wetland areas. This effort identified the importance of duck clubs in providing habitat for a variety of species.

Surface gradients in developed wetlands are so shallow, a one-inch change in water level can move pond shorelines hundreds of yards. Because of this gradient, water control is the primary means of managing vegetative growth and these wetlands have extensive, precise water control systems. One 3,346-acre duck club has 18 managed

water levels, 88 water control structures, over 18 miles of channels and 21 miles of dikes. Precise water control is required to prevent avian botulism which can kill tens of thousands of birds, to minimize pond siltation and to control carp and other undesirable exotics.

Water shortages can cause vegetation damage and changes that may contribute to disease epidemics resulting in bird mortality. To maintain healthy marshlands, a flush of water is required to wash out toxins and provide salinity control during the spring.

Critical issues for duck club managers include securing adequate water supply, delivery timing and reliability and maintaining water quality. Flooding issues are significant since these properties are located at low elevations near the lake and most owners or managers rebuilt after the 1980s flooding. Other pressing issues include access, road maintenance, predator control, trespass grazing and non-native plant species invasions which require ongoing control and expensive eradication.

### Important Island Habitat Areas

In addition to established WMAs and privately managed habitats, the islands of GSL provide isolated habitat for a variety of colonial and migratory birds. The following table was used in the *"Linking Communities, Wetlands and Migratory Birds*" document to describe the islands of the lake, access and wildlife use (Wetlands International, 1998) (Table 8).

Table 8. GSL Island Management, Acreages, Public Access and Wildlife Use

| Island Name | Managing Agency | Acreage | Public Access | Wildlife Use |
|---|---|---|---|---|
| Antelope Island | DPR | 28,240 | Yes | Antelope, bison, deer, bighorn sheep, many birds and other wildlife species |
| Stansbury Island | BLM/Private | 22,314 | Partial | |
| Fremont Island | Private | 2,945 | No | Unknown |
| Carrington Island | BLM/Private | 1,767 | Yes | |
| Gunnison Island | DWR | 163 | No | Pelican rookery, gulls |
| Dolphin Island | Sovereign Land | 60 | Yes | |
| Bird or Hat Island | DWR | 22 | No | Gull and heron rookery |
| Badger Island | Sovereign Land | 6 | Yes | |
| Cub Island | BLM | 1 | Yes | |
| Egg Island | Sovereign Land | 1 | Yes | Gull rookery closed 4/1-7/31 |
| White Rock Island | Sovereign Land | 1 | Yes | Gull rookery closed 4/1-7/31 |

Census work by DWR will better define wildlife use on the islands in the lake. Dependent upon lake elevation, there may be more or fewer islands than those listed above.

## Changes in Lake Brine Salinities

### Segregation of Great Salt Lake Waters into Distinct Salinity Areas

The waters of GSL are segregated into four areas of different salinity. (Bear River Bay, Farmington Bay, Gilbert Bay and Gunnison Bay) Each is influenced by differing water inflow and evaporation regimes, which results in changes to lake elevation and salinity.

In this discussion, the south arm of the lake is different from Farmington Bay and Bear River Bay. Salinities in the south arm have ranged from 5-21 percent in recent times. In August 1999, salinity was approximately eight percent. It is this portion of the lake that is being harvested for brine shrimp and supports abundant bird populations.

Farmington Bay is that portion of the lake east of Antelope Island and isolated from the rest of the lake by the Davis County Causeway and the Antelope Island Southern Causeway. Salinities of Farmington Bay fluctuate substantially due the inflow of freshwater from the Jordan River, and the causeway-inhibited exchange of salt water from the south arm. Salinity values have ranged from 2-6 percent in recent times. Commercial harvesting of brine shrimp is prohibited in

this area to minimize impacts to bird populations, which are substantial.

Bear River Bay lies north of the causeway (Bagley Fill), on the east side of Promontory Point. Water salinity in this bay can also fluctuate substantially, but is usually very low (<2 percent). There is evidence that when the Bear River flows are very low, a layer of dense brine runs northward into the bay, especially during periods of south winds (Butts, 1998). Commercial harvesting of brine shrimp is also prohibited in this bay to minimize impacts to substantial bird populations, especially fish-eating birds.

The north arm of the lake (Gunnison Bay) lies north of the northern railroad causeway between Promontory Point and Lakeside. Salinities in this portion of the lake have ranged from 14.5-28.4 percent in recent times. In August 1999 salinity was approximately 23 percent. There has been very little harvesting of brine shrimp in this portion of the lake. The water of the north arm is too saline to sustain meaningful populations of shrimp. Periodically, some shrimp and cysts wash through the breach and culverts, and there are a few locations in the north arm where brine shrimp populations may occur, probably due to springs which dilute brine salinity. As salinities decrease, brine shrimp populations will increase. In fact, meaningful populations have historically existed and been harvested from the Gunnison Bay. Commercial brine shrimp harvesting is allowed in the north arm. In fact, most brine shrimp harvesting during 1999-2000 occurred only in the north arm of GSL. Bird use of the north arm of the lake has been severely limited because of the lack of viable brine shrimp populations, although some foraging occurs near the causeway breach and culverts. Gunnison Island is an important White pelican nesting area.

## Aquatic Biota Differences

Of primary concern to wildlife managers is the current degree of difference in salinities between the north and south arms of GSL and the lack of brine shrimp productivity in the north arm and diminished cyst production in the south arm. Because brine shrimp are currently managed and considered a focus species, most of the research and attention has centered on brine shrimp. However, the same low productivity concerns extend to other aquatic species which are significant in the lake's food chain, such as algae and brine flies.

The northern railroad causeway from Promontory Point to Lakeside is inhibiting the exchange of lake brines between the north and south arms of the lake, and has caused a significant difference between the salinities of the north and south arms since its completion in the late 1950s. It is now thought that the differential, which has averaged between 10-13 percent, is increasing ("Water-Chemistry" section). Because brine shrimp and brine fly productivity in the north arm has been severely limited, and south arm production has declined, substantial negative impacts on avian species are suspected. Wildlife managers are concerned about the causeway's impact on the lake's ecology.

Brine shrimp populations flourished in the north arm of the lake during the mid-1980s, due primarily to high lake levels and resulting lower than average salinities in the north arm. It has been suggested that, at some lake levels, a differential in brine concentrations is beneficial because when the south arm is

too dilute to support a healthy brine shrimp population, the north arm may be able to. At historically high lake levels, that appears to be the case.

In 1999, salinities in the south arm have diminished to the point where the brine shrimp population is stressed and substantially reduced, while salinities in the north arm continue to be high enough to prevent the establishment of a significant, viable brine shrimp population. The south arm has experienced reductions in brine shrimp harvest and salinity.

Table 9. Brine Shrimp Harvest and South Arm Salinity

| Year | Harvest (million lbs.) | South Arm Salinity |
|---|---|---|
| 1996 | 14.7 | 12-13% |
| 1997 | 6.1 | 11-12.6% |
| 1998 | 4.6 | 8.7% |
| 1999 | 2.5* | 7.3% |

*The south arm was closed to harvesting during the 1999-2000 season. Most of the biomass was harvested from the north arm.

These salinity ranges occurred during the brine shrimp production season and were measured at a sample site located in the open water area of the south arm. This circumstance has resulted in a depressed shrimp population in the lake with negative impacts on bird populations and commercial harvesting of brine shrimp (Table 9).

Research on both the hydrology of the lake and the role of salinity in brine shrimp and other aquatic population ecology is continuing.

## Lake Water Quality Impacts to Wildlife

A discussion of GSL water quality issues, studies and initiatives appears in the "Water-Quality" section of this statement. Little is known about the impacts of water contaminants on GSL wildlife. A research project sponsored by USFWS is expected to provide information focusing on Bear River Bay in the near future. That document will represent the latest understanding of the dynamics of water contaminants and will likely help chart the future of water quality research on GSL.

## Lands Designated for Wildlife Management

Section 23-21-5 of the Utah Code provides;

> "The Wildlife Board is authorized to use any and all unsurveyed state-owned lands below the 1855 meander line of the GSL within the following townships for the creation, operation, maintenance and management of wildlife management areas, fishing waters and other recreational activities..."

The Code identifies all or part of 39 townships lying within the meander line of the lake (Appendix F, Exhibit 2). Some of the area within the identified townships has been formally placed within WMAs by the Board of Wildlife Resources, but much has not. The management status and responsibility for the lands identified as available for wildlife management by statute is unclear for those which have not yet been evaluated and acted upon by the Board of Wildlife Resources. DWR will initiate the process to consider the designation of these lands.